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DEVELOP AND TEST FUEL CELL POWERED ON SITE INTEGRATED TOTAL ENERGY SYSTEMS: PHASE III, FULL-SCALE POWER PLANT DEVELOPMENT

13TH QUARTERLY REPORT: MAY - JULY 1984

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SECTION I. INTRODUCTION

Engelhard's objective under the present contract is to contribute substantially to the national fuel conservation program by developing a commercially viable and cost-effective phosphoric acid fuel cell powered on-site integrated energy system (OS/IES). The fuel cell offers energy efficiencies in the neighborhood of 40% of the lower heating value of available fuels in the form of electrical energy. By utilizing the thermal energy generated for heating, ventilating, and air-conditioning (HVAC), a fuel cell OS/IES could provide total energy efficiencies in the neighborhood of 80%. Also, the Engelhard fuel cell OS/IES, which is the objective of the present program, offers the important incentive of replacing imported oil with domestically produced fuel.

Engelhard has successfully completed the first two phases of this program. The culmination of the pre-commercialization program will be the integration of the fuel cell system into a total energy system for multi-family residential and commercial buildings. The mandate of the current Phase III effort is to develop a full-scale 50kW breadboard power plant module and to identify a suitable type of application site. An accomplished objective in Phase III was the integration and testing of the 5kW system whose components were developed during Phase II. In addition to the development and testing of this sub-scale system, scale-up activities have been carried out under Phase III. Throughout this program, continuing technology development activity will be maintained to assure that the performance, reliability, and cost objectives are attained.

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SECTION II. TECHNICAL PROGRESS SUMMARY

TASK I - 5kW POWER SYSTEM DEVELOPMENT

The objective of this task was to complete integration of the 5kW components and sub-systems developed during Phase II.

Steady-load testing of the 5kW integrated system, with regular shutdowns, was completed during August 1983. Subsequently, load-following testing was carried out successfully, as the system was operated in the fully-automatic mode. (See the August-October 1983 Quarterly Report.)

Further testing of this integrated system will be conducted as time permits.

TASK II - ON-SITE SYSTEM APPLICATION ANALYSIS

The purpose of this task was to develop an application model for on-site integrated energy systems. The model considers fuel availability, costs, building types and sizes, power distribution requirements (electrical and thermal), waste heat utilization potential, types of ownership of the OS/IES, and grid connection vs. stand-alone operation. The work of this task was carried out under subcontract by Arthur D. Little, Inc. (ADL), and this work has been completed. The main conclusions are summarized in the May-July 1983 Quarterly Report.

TASK III - ON-SITE SYSTEM DEVELOPMENT

This task forms the core of the Phase III contract effort. Work under this task will result in the breadboard design of a system for an on-site application. The power plant will be designed for a rated output of 50kW (electrical) or some multiple thereof. The fuel processor and power conditioner will each be 50kW units, while the 50kW fuel cell will comprise two 25kW stacks. This task is accordingly broken down into four sub-tasks as follows:

III-1. Large Stack Development
III-2. Large Fuel Processor Development
III-3. Overall System Analysis
III-4. Overall System Design and Development

The 1984 activities under this contract are focusing on Sub-Task III.1 Further effort on the other sub-tasks will be carried out under private sponsorship.

SUB-TASK 1. LARGE STACK DEVELOPMENT

Stack No. 1 in the 1984 series (25-cell, 13 in. x 23 in.) was assembled during May and has been on load for about 1900 hours; operation continues to be satisfactory on hydrogen and air. The stack terminal voltage is currently 15.6V at 161mA/cm^2. The distribution of voltages in this stack is shown in Figure 1.

SECTION II. - CONTINUED

Stack No. 2 in the 1984 series (25-cell, 13 in. x 23 in.) was assembled and placed on load during June. The components incorporated into this stack are essentially the same as those used in Stack No. 1. It has been on load for about 800 hours, and this stack is performing satisfactorily. The terminal voltage is 15.9V at 161mA/cm^2. The distribution of voltages is shown in Figure 2.

Implementation of protection control systems for the 25-cell stacks is proceeding. These systems have been designed to respond to factors that cause upsets in stack operation and, in doing so, minimize potential damage to the stacks; such factors are loss of fuel, loss of air, loss of house power, over-temperature, and under-temperature.

Several stack upsets were experienced during the reporting period, and these have resulted in performance degradation in all stacks. However, Stack No. 2 benefited from the recent installation of a protection control system in its test station. This provided a nitrogen purge through the fuel and air ports when an electrical power shutdown and attendant hydrogen supply interruption occurred during an overnight period. No significant performance loss was sustained, whereas Stack No. 1 and other stacks operating in the laboratory with no protection control systems incurred noticeable losses.

The synthetic-reformate mixing station for the 25-cell stacks has been installed, and calibration and trouble-shooting are being carried out. Use of reformate fuel for Stack No. 1 and Stack No. 2 will begin during the first week of August.

SUB-TASK 2. LARGE FUEL PROCESSOR DEVELOPMENT

Test activity for the 50kW fuel processing sub-system is currently in abeyance. This activity will be resumed later in 1984 in conjunction with the 25kW stack test program.

SUB-TASK 3. OVERALL SYSTEM ANALYSIS

The Physical Sciences Inc. subcontract has been completed. Final reports involving the off-design and transient analysis portions of the work have been received. The corresponding computer modules have been integrated into the overall fuel cell system program, and these have been successfully utilized in-house.

SUB-TASK 4. OVERALL SYSTEM DESIGN AND DEVELOPMENT

The Trane Co. has completed work under its subcontract to Engelhard. The main conclusions of Trane's study with respect to the HVAC sub-system and the utilization of waste heat are summarized in the May-July 1983 Quarterly Report.

TASK IV - STACK TECHNOLOGY

The purpose of this task, which will continue throughout the contract, is to investigate new materials and component concepts through bench-testing and stack trials. The criteria for selecting activities under this task are the prospects for improved

performance, reduced costs, or improved reliability. Improvements in the performance of electrocatalysts, generated under Engelhard-sponsored Task VI, are reported under Task IV.

A. PERFORMANCE OPTIMIZATION

CATALYSTS

Performance comparison between cathode catalysts E-1 (baseline) and E-7 (developmental) continues to be provided through the ongoing testing of 1983 Stack No. 3. Figure 3 illustrates that, although losses were sustained by both catalyst types, the performance differential in favor of E-7 has been sustained through about 4800 hours. The losses are for the most part attributed to hot open-circuit exposure following house power outages and subsequent fuel supply interruptions, as indicated by the vertical arrows in Figure 3 (see Sub-Task III.1 above).

A performance comparison between two developmental cathode catalysts (E-3 and E-7) is being provided through the testing of Stack No. 1 and Stack No. 2 in the 1984 series. The average disparity of performance between the E-3 cathodes and the E-7 cathodes is about 15mV for Stack No. 1 (about 1900 hours) and about 10mV for Stack No. 2 (about 800 hours), each in favor of E-7.

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REDUCED CELL IR-LOSS

The "rebuild" of 1983 Stack No. 4 (10-cell, 10.7 in. x 14 in.) was started on test at the end of March. As in the original build, this stack comprised cells with electrolyte-matrix configurations that were modified in order to attain lower IR-loss (see Appendix). The rebuild involved altered procedures that were primarily related to sustaining electrolyte inventory in the matrix through the first few days, during which time the demand for acid by other cell components is greatest.

There were two weak cells in this stack; and, although these improved somewhat, their performance level was not much above 0.5V. The open-circuit voltage of the stack overall was acceptable, though erratic, as shown in Figure 4. On the other hand, the performance on load, while also erratic, clearly showed poorer stability than that of a typical stack, as shown in Figure 5. The stack has been shut down.

B. COST REDUCTION

LARGER CELL SUB-STACKS BETWEEN COOLING PLATES

The use of five cells per cooling plate has been carried through to the two 25-cell, 13 in. x 23 in. stacks (No. 1 and No. 2). Comprehensive thermal data will be obtained later in the test program.

C. RELIABILITY

AUTOMATED ELECTROLYTE-REPLENISHMENT SYSTEM

1983 Stack No. 3 (11-cell, 10.7 in. x 14 in.) continues to operate with the automated electrolyte-replenishment system that had been successfully demonstrated in 1983 Stack No. 1. This system is performing successfully to date (4800 hours on load) in 1983 Stack No. 3. This is illustrated in Figure 6, which shows the open-circuit voltage history.

NON-METALLIC COOLING PLATES

1983 Stack No. 3 continued to operate successfully throughout the reporting period with non-metallic cooling plates (see above). The steady-load performance history to date is shown in Figure 7. As discussed in A., above, the vertical arrows indicate periods during which losses were sustained through hot open-circuit exposure.

TASK V - FUEL PROCESSING SUPPORT

The intent of this task was to provide background data and information to support the design and construction of an optimized 50kW fuel processor under Task III. Most of the effort of this task was devoted to screening and longevity testing of catalysts for steam reforming of methanol. This task is now complete.

TASK VI - IMPROVED ELECTROCATALYSTS

Developmental electrocatalyst formulations are being prepared under Engelhard sponsorship. These are provided to the main program, and results are reported under Task IV.

Development work is being pursued on both cathode and anode catalysts; however, the major activity at the present time is directed toward improved cathode activity (see Task IV).

SECTION III. CURRENT PROBLEMS

None.

SECTION IV. WORK PLANNED

TASK IV - STACK TECHNOLOGY

- Continue testing of Stack No. 1 and Stack No. 2.
- Initiate use of synthetic reformate fuel.
- Continue evaluation of non-metallic cooling plates in 1983 Stack No. 3.

- 25 Cells, 13 in. x 23 in.
- Current Density: 150 A/ft^2 (161mA/cm^2)
- H_2-Air
- Anode Catalyst: A-1 (0.46mg Pt/cm^2)
- Cathode Catalyst: E-3 and E-7 (0.46mg Pt/cm^2)

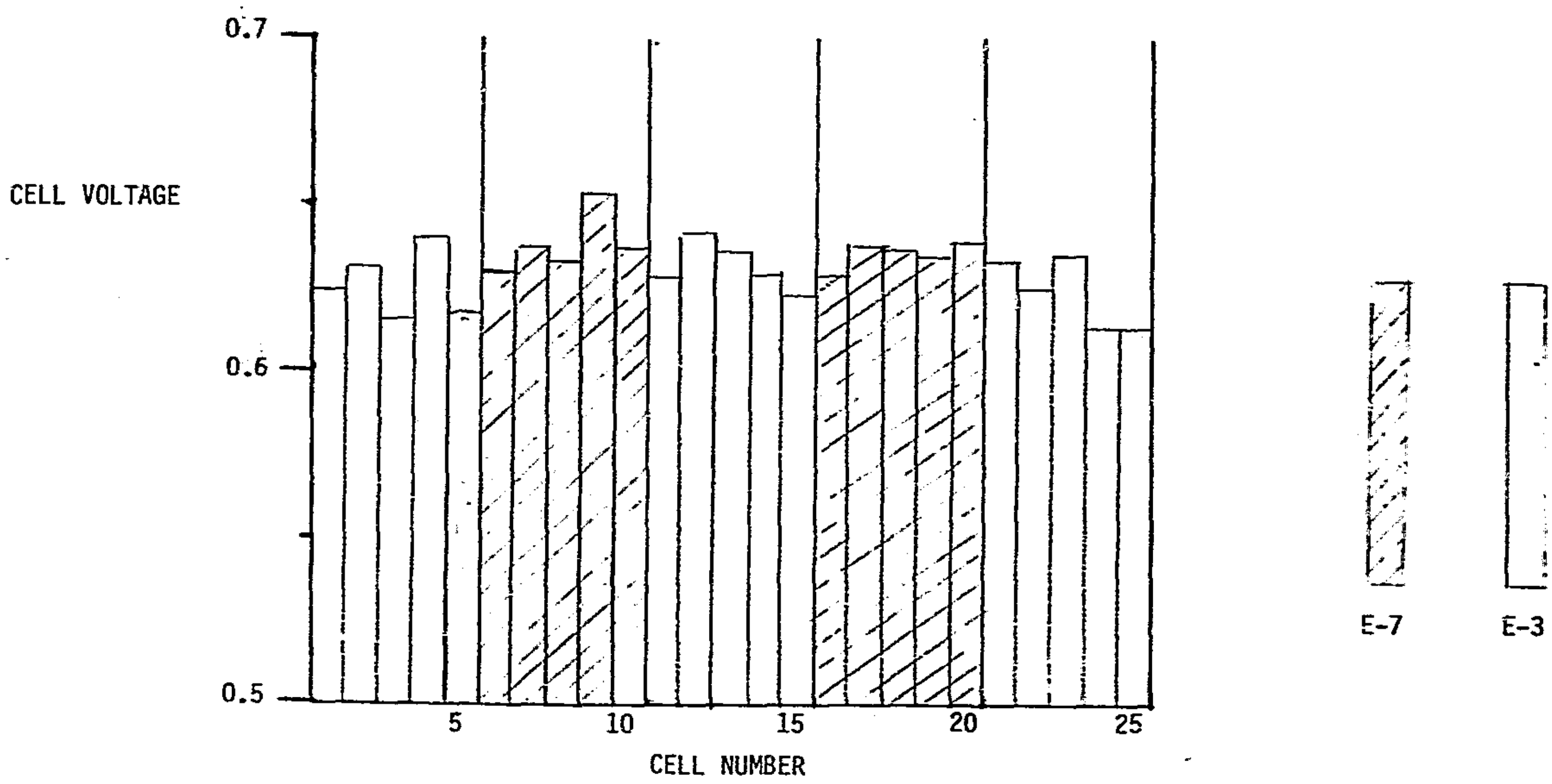

FIGURE 1 CELL VOLTAGES IN STACK NO. 1

- 25 CELLS, 13 IN. X 23 IN.
- CURRENT DENSITY: 150A/ft^2 (161 mA/cm^2)
- H_2-AIR
- ANODE CATALYST: A-1 (0.46mg Pt/cm^2)
- CATHODE CATALYST: E-3 AND E-7 (0.46mg Pt/cm^2)

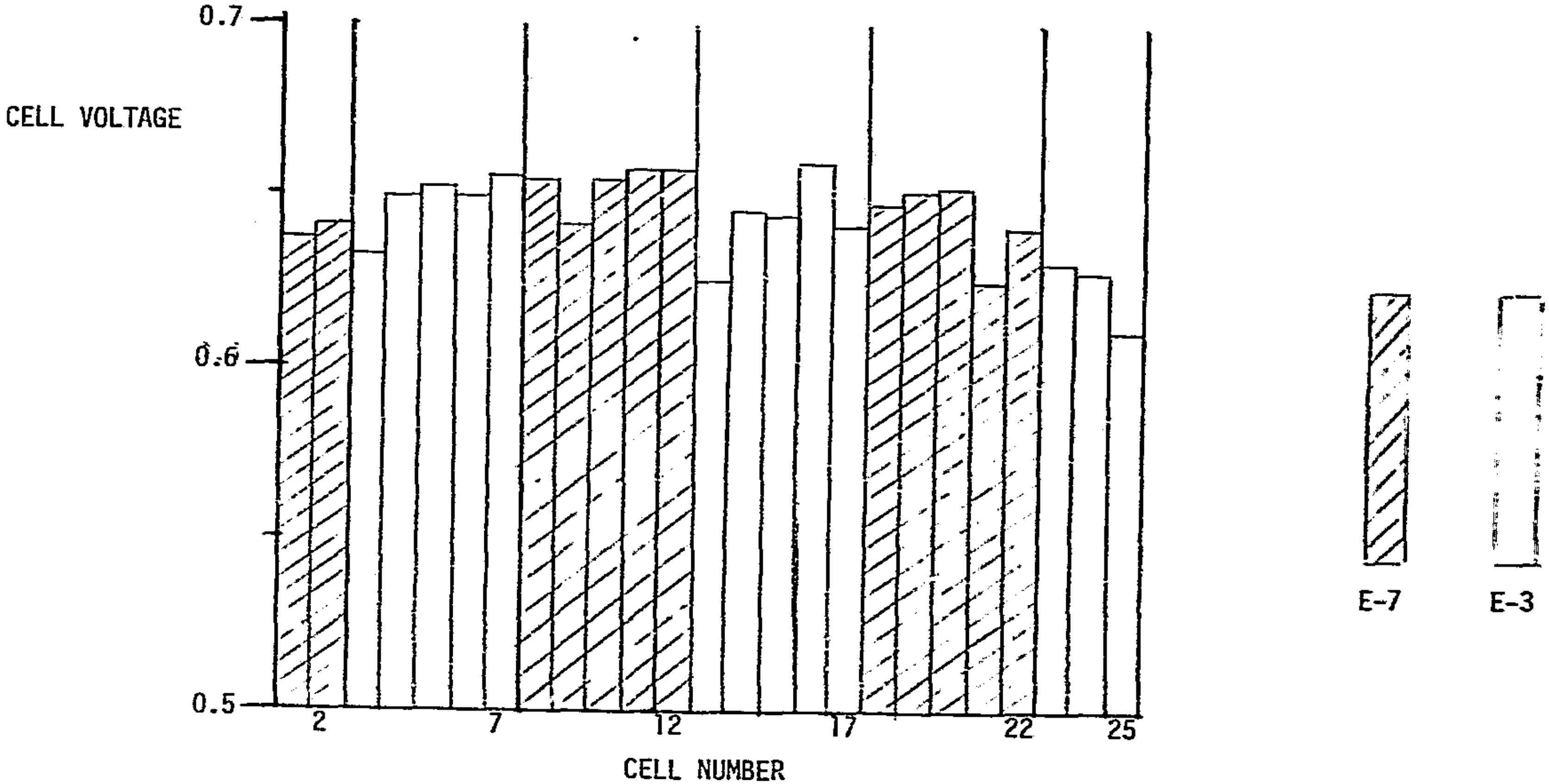

FIGURE 2 CELL VOLTAGES IN STACK NO. 2

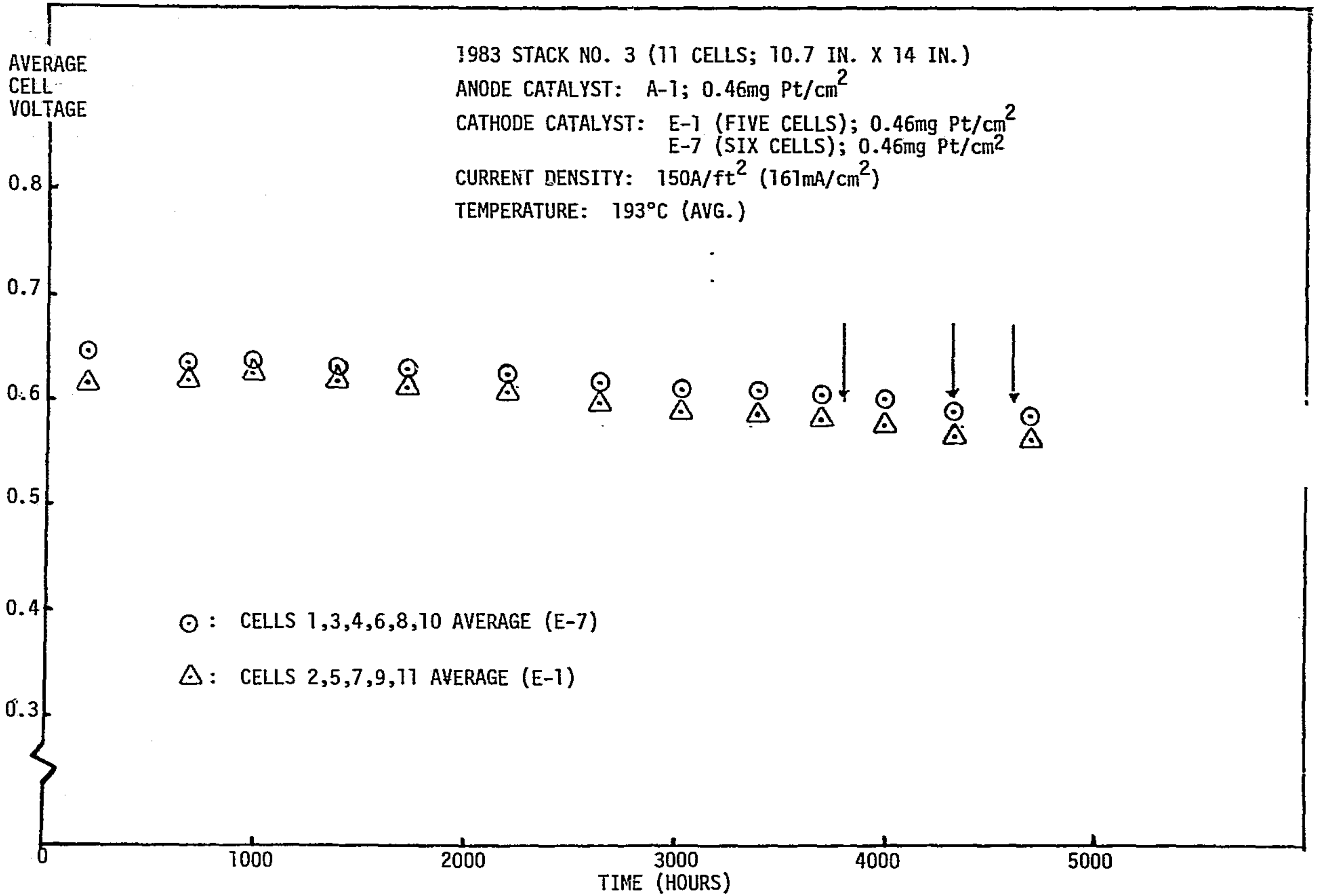

FIGURE 3 AVERAGE CELL VOLTAGE FOR CATHODE CATALYSTS IN 1983 STACK NO. 3

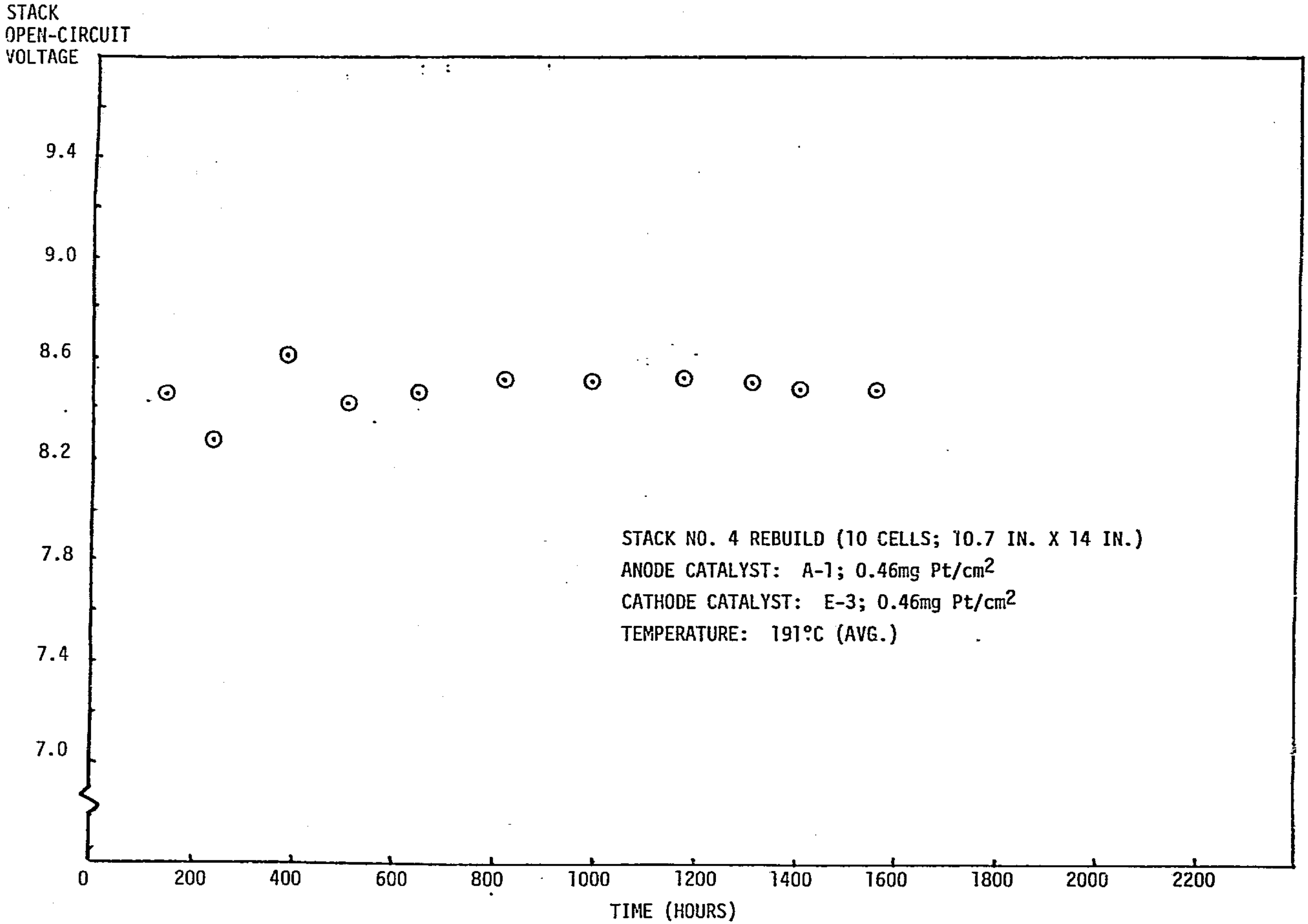

FIGURE 4 OPEN-CIRCUIT VOLTAGE OF STACK NO. 4 REBUILD (1983 SERIES)

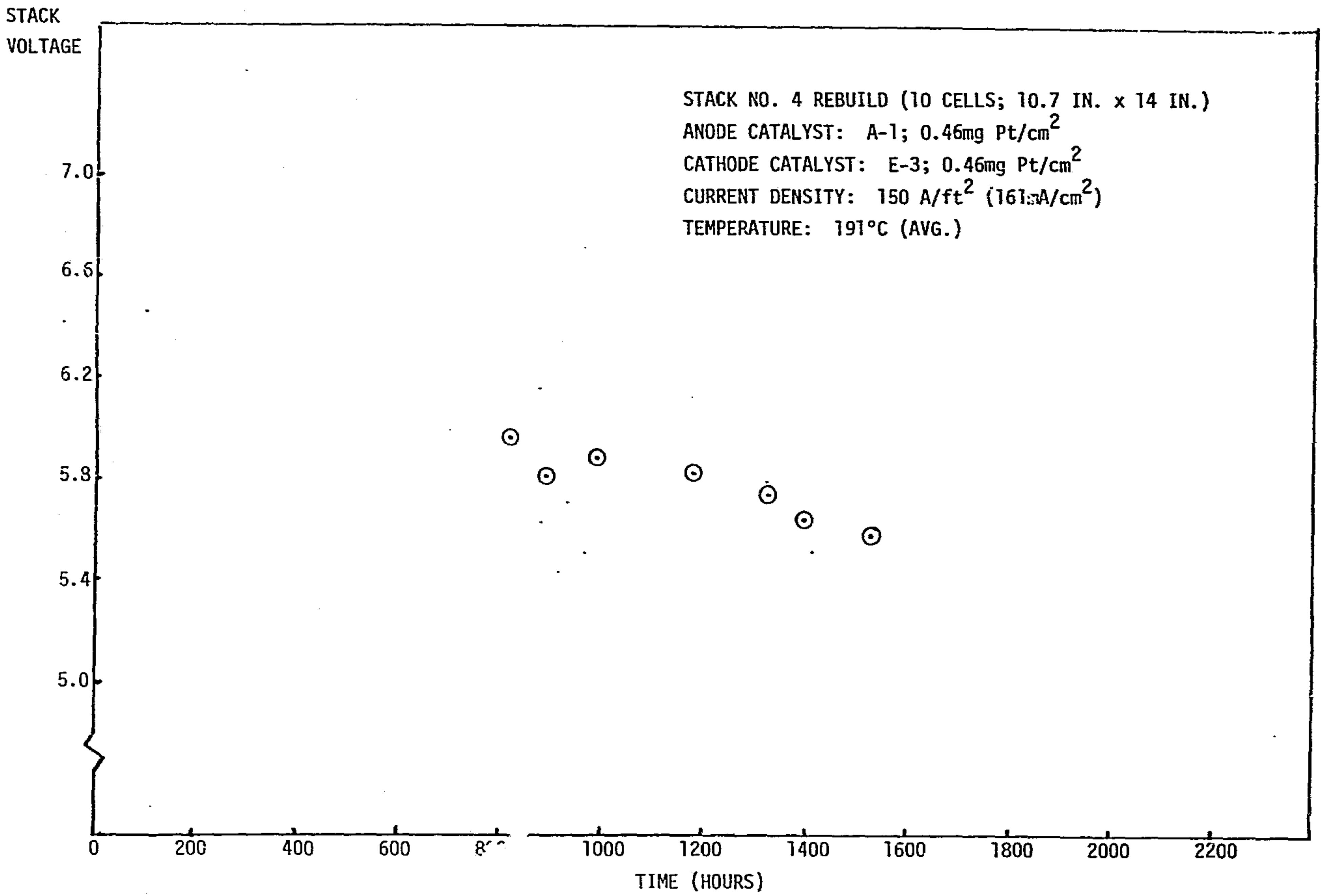

FIGURE 5 STEADY-LOAD PERFORMANCE OF STACK NO. 4 REBUILD (1983 SERIES)

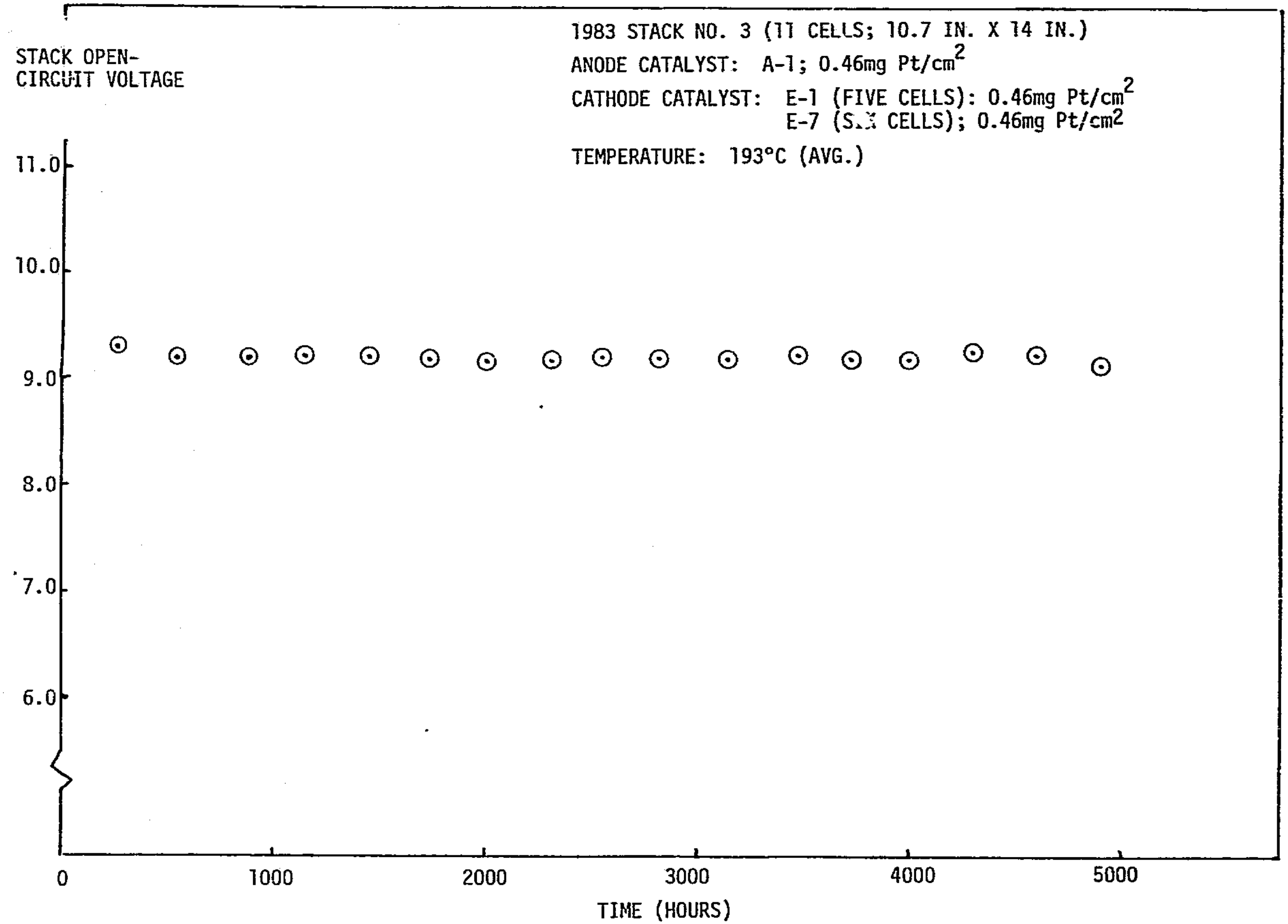

FIGURE 6 OPEN-CIRCUIT VOLTAGE HISTORY OF 1983 STACK NO. 3

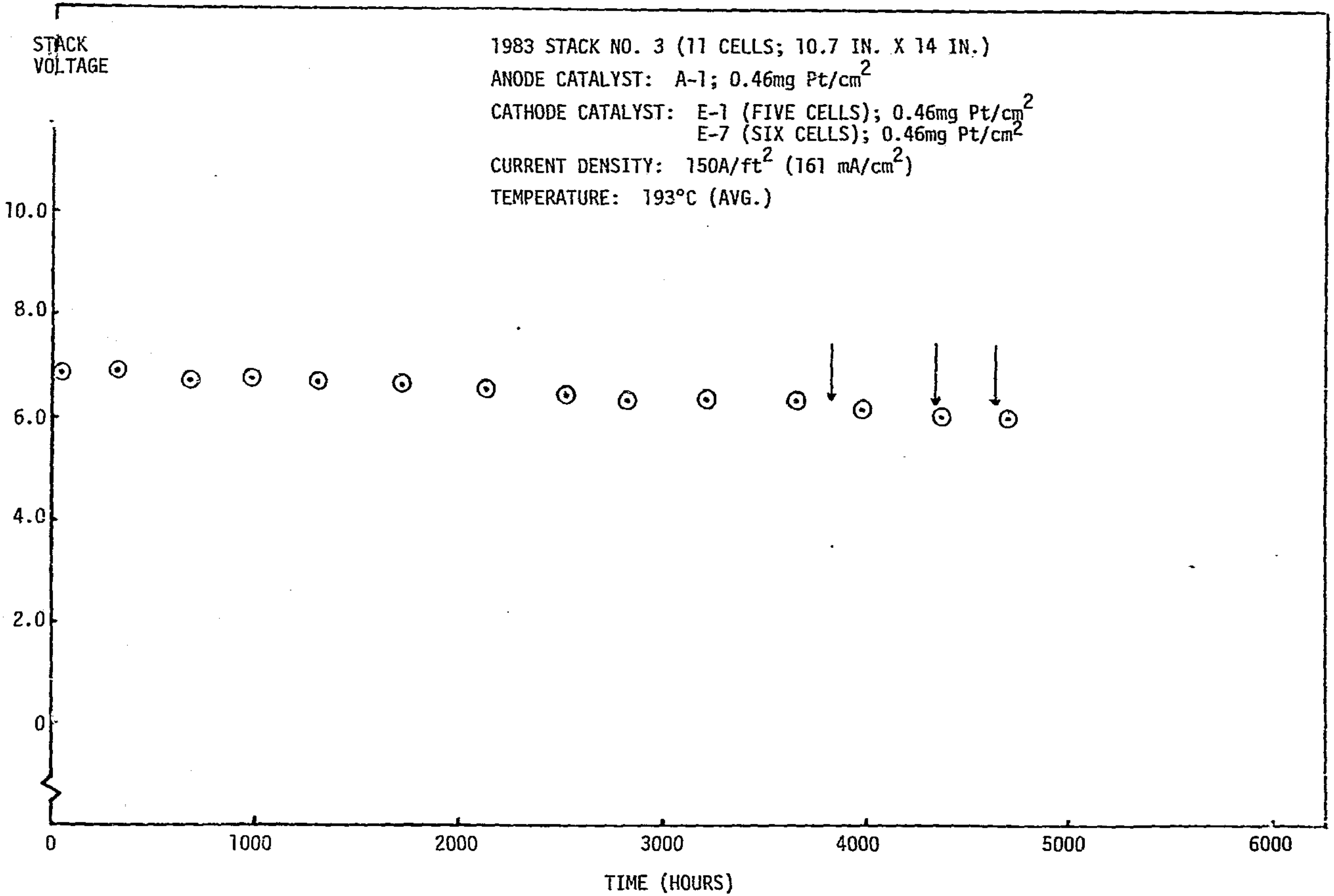

FIGURE 7 STEADY-LOAD PERFORMANCE OF 1983 STACK NO. 3